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Logic Controlled Cassette Deck Mechanism"DK-76"

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Fujitsu Ten marketed an eight-track stereo tape-player for use in automobiles in 1967. Later, compact players for music cassette tapes developed by Philips of the Netherlands became predominant for use in automobiles. Recently, compact disk (CD) players and digital audio tape (DAT) players have been added to the automotive market. We have continued effort to develop these players and have marketed car stereo sets.

The new cassette deck DK-76 has been designed with emphasis on sound quality, fashionable design, and reliability to fulfill the recent user needs which are increasingly diversifying and are aiming at higher sophistication. To meet such needs, we have adopted a new mechanism and new methods for the structure of the DK-76 and have installed a microprocessor dedicated to control the cassette deck.

This paper outlines the features and design points of the DK-76.

1. Introduction

Users of car audio equipment in Japan emphasize sound quality. In addition to conventional compact cassettes (hereafter called cassettes), compact disks (hereafter called CD) and digital audio tape (hereafter called DAT) have been added as music media. The dominant media is still cassettes. The number of cassette decks shipped continues to increase.

Car audio equipment must have a long life and be of high quality. High sound quality, fashionable design and high reliability are required.

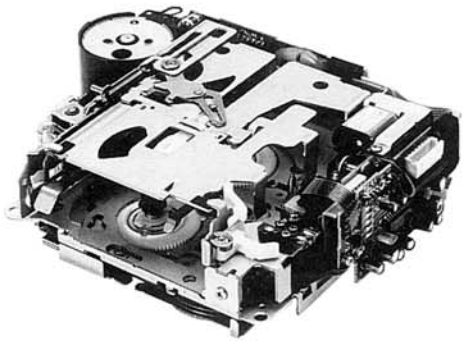

Figure 1. The DK-76 cassette deck

This paper discusses the features and design points (new mechanisms and control circuit) of the DK-76 cassette deck which has recently been developed. Figure 1 shows the DK-76.

2. Objectives of development

The background under which the DK-76 was developed is explained below, focusing on the market trends, target, and approach for determining specifications.

2.1 Market Trends

Figure 2 shows the number of car audio sets by product type shipped during these years in Japan (quoted from a repart of the Electronic Industries Association of Japan). The shipment of radio sets on an annual basis has decreased — from 7,170 thousand units in 1985 (58% of the total shipment) to 5,040 thousand (39%) units in 1989. The shipment of cassette decks, including cassette decks fitted with a radio, is steadily increasing — from 5,570 thousand units (42% of the total shipment) in 1985 to 7,400 thousand units (57%) in 1989. The shipment of CD players began in 1985. It has remarkably increased since 1988 and reached 600 thousand units (4%) in 1989. Automotive DAT players were first marketed in 1987.

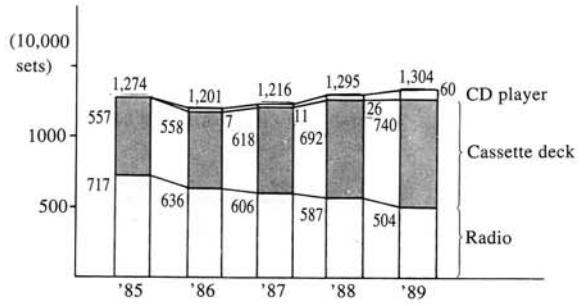

Figure 2. Annual shipments of car audio products in Japan

They have not become popular yet. This is due to the copyright problem. As outlined above, the cassette player remains the most popular entertainment device for automobiles.

2.2 Product target

The DK-76 will be shipped to automobile manufacturers and other buyers. It will be not only marketed as Fujitsu Ten's product, but will also be supplied as Fujitsu Ten's first OEM product to other car audio equipment manufacturers.

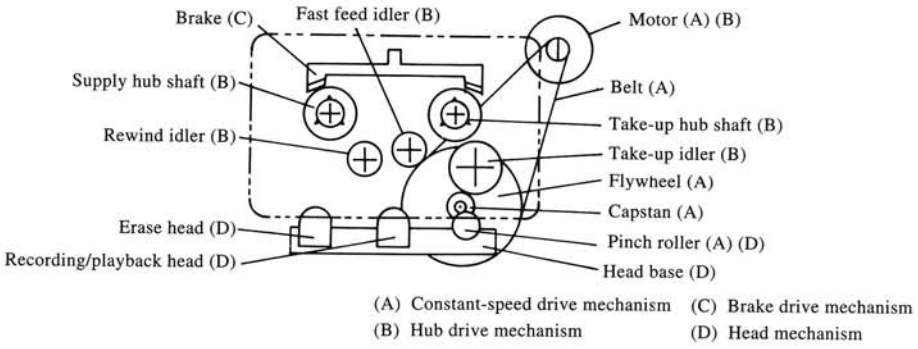

Figure 3. Cassette deck mechanism (1)

2.3 Approach for determining specifications

The purpose of the development is to supply a high-quality, sophisticated cassette deck. Sophistication means ① good sound quality and ② a fashionable design. High quality means a low failure rate that allows the system to work reliably when the car is operating in a harsh environment. To achieve this purpose, we thoroughly investigated products currently being marketed and decided on the specifications needed to achieve high quality and fulfill the requirements for a new cassette deck.

3. Overview of the cassette deck

The DK-76 has a microprocessor to control a wide range of operations.

3.1 Structure and operation of cassette deck

Figures 3 and 4 show how the cassette deck is constructed and how it operates.

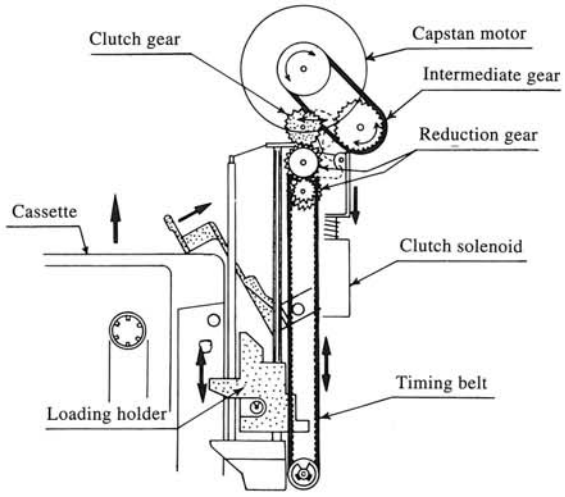

Figure 4. Cassette deck mechanism (2)

Table 1. Rating and performance of the DK-76

	Item	Specification
Rating	Applicable cassette tape	Philips-compatible compact cassette tape
	Type of cassette deck	Vertical-insertion, cassette deck with an auto-reverse function
	Playback	Four-track, two-program, stereo playback
	Tape speed	4.76 cm/second
	Supply voltage	13.2 VDC
	Dimensions	133(W)×33.8(H)×108(D) mm
	Weight	450 g
Performance	Wow and flutter	0.07% (JIS WRMS)
	Frequency characteristics	30 Hz to 18 kHz (±3 dB)
	FF/REW time	95 seconds (C-60)
	Loading time	4 seconds
	Force for cassette insertion	400 g

Table 2. Comparison in function

	Item	Specification		
		DK-76	Company A's product	Company B's product
Functions	Motor loading	○	○	○
	Automatic ejecting	○	○	○
	Azimuth alignment	Dual	Dual	Dual
	Motor	EG	EG	EG
	Automatic program selection (APS) and repeat	○	○	○
	Music scan and blank sip	○	○	○
	Automatic tape selector	○	○	○
	Tape slack elimination	○		○
	Mechanical brake for take-up reel	○		○
	Grooved head	○	○	
	Dedicated microprocessor for desck control	○		

Note: A circle indicates that the function is installed.

The cassette deck mechanism consists of the following components, each corresponding to a particular function: the constant-speed tape drive, hub drive (take-up reel), magnetic head (hereafter called head), pinch roller slide mechanism, cassette loading/ejecting mechanism, and others.

3.1.1 Constant-speed tape drive

The constant-speed tape drive operates as follows: The shaft of the driving capstan turns to draw straight the tape held between the driving capstan and the driving pinch roller by means of friction at a constant speed.

3.1.2 Hub drive

The hub drive takes up the drawn tape evenly by applying constant tension to the hub of the cassette. For this purpose, it has a slip mechanism.

3.1.3 Slide mechanism for head and pinch roller

This mechanism slides the head base to put the capstan shaft into contact with the pinch roller and put the head into contact with the tape or to separate the capstan shaft and the head apart from the pinch roller and the tape, respectively.

3.1.4 Cassette loading/ejecting mechanism

General cassette loading/ejecting methods are front loading for automotive cassette decks and top loading for home cassette decks. The front loading method is explained here. Figure 4 shows the mechanism adopted in our cassette deck. With the capstan motor as the drive power, the cassette is loaded and ejected through the opening for the cassette by way of sliding the loading holder.

3.2 Specification

Table 1 lists the rating and performance of the DK-76. Table 2 lists a comparison in function between the DK-76 and competitive products.

4. Features

This chapter explains three major features of the DK-76.

4.1 Improved sound quality

For high sound quality, it is effective to reduce electro-magnetic noise from the motor. To achieve good sound quality, we studied appropriate positions of the motor and head and adopted an electronic governor

motor (hereafter called EG motor) featuring low electromagnetic noise in order to improve the S/N ratio.

4.2 Improved aesthetics

We have designed the DK-76 so that all operations are performed smoothly and quietly, including manual cassette insertion and the various cassette deck operations. The cassette loading mechanism uses an upper-bias method, and the mechanism for switching between fast tape feed (FF) and rewind (REW) is motor-driven. These features help improve the aesthetics.

4.3 High reliability

To achieve high reliability, we have designed the mechanism so that the life will be prolonged. To prolong the life, it is necessary to reduce the friction of sliding components. For the DK-76, the slip mechanism and motor have been improved. The DK-76 also takes advantage of microprocessor control, and incorporates many software-controlled fail-safe features for protection of the tape and mechanism.

These features make the DK-76 competitive in the market in both life and reliability.

5. Key points in design

This chapter explains the mechanisms and control methods newly developed to achieve the objectives of the DK-76 development.

5.1 New mechanisms

5.1.1 EG motor

Conventional mechanical governor motors (hereafter called MG motors) emit a large amount of noise because large sparks are generated from mechanical

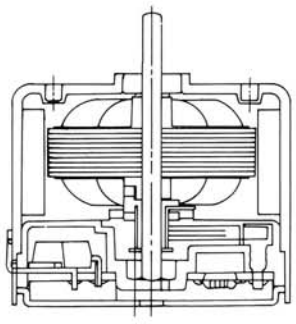

Figure 5. Structure of EG motor

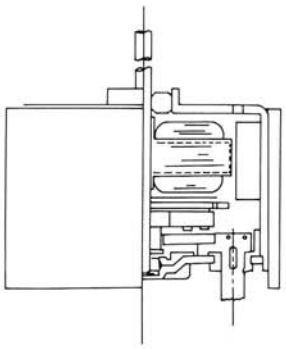

Figure 6. Structure of MG motor

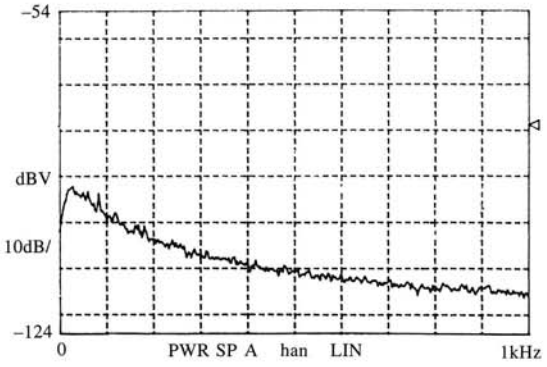

Figure 7. Motor noise of the DK-76

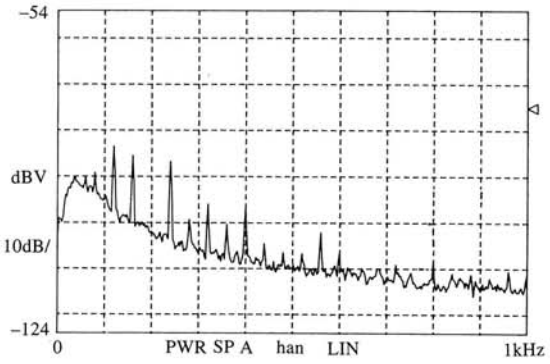

Figure 8. Motor noise of conventional cassette deck

contacts which are used to control the speed of rotation. Also, wear of the contacts limits the life of the motor. In contrast, electroric governor (EG) motors are free of mechanical contacts and generate sparks only from between the brush and commutator. Their structure is advantageous in electric noise suppression. Figure 5

shows the structure of the EG motor and Figure 6 shows that of the MG motor. The distance between the motor and head has been doubled in comparison with conventional products to reduce the influence of electro-magnetic noise on the head. Figures 7 and 8 shows noise characteristic of the EG and MG motors.

5.1.2 Operation selector mechanism

In developing the DK-76, we have tried to reduce the noise generated when a cassette operation is selected and when the tape is being fast-forwarded or rewound. To achieve this, we have adopted a number of measures.

The method we have adopted to reduce noise involved in operation selection is using motor drive. Since conventional cassette decks use a plunger drive, a somewhat loud sound is emitted when the plunger bumps. The new mechanism using no plunger has made operation noise extremely low. The new mechanism is also used for switching between PLAY and FF/REW. Figure 9 shows the structure of the operation selection mechanism in the DK-76 and Figure 10 shows that of the conventional product. Figure 11 shows the operation noise frequency spectra from the DK-76 and Figure 12 shows that for the conventional product.

5.1.3 Slip mechanism

A large number of automobile manufacturers have decided to guarantee their products for three years. In response to the requirement for long life, we have improved sliding components in order to reduce friction. The new structure adopted for the slip mechanism which takes important part in tape take-up is explained below.

The slip mechanism has a sliding surface that continuously slides so that the take-up hub in the cassette can continuously take up the tape which has been drawn at a constant speed from between the capstan shaft and the pinch roller. Therefore, when the slip surface is worn, the slip mechanism becomes useless. The slip mechanism in the DK-76 uses double-side slipping in contrast with one-side slipping in the conventional mechanism. Also, components are separated for PLAY and for FF/REW so that both low torque during PLAY and long-period stable torque can be obtained. Figure 13 shows the slip mechanisms in the DK-76 and conventional product. Figure 14 shows how the take-up torque changes during continuous play operation.

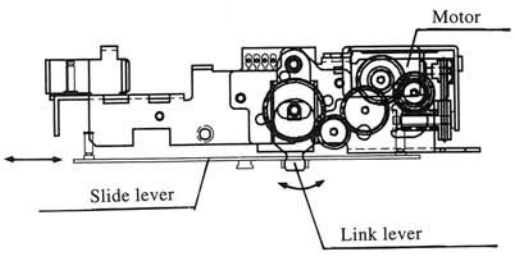

Figure 9. Structure of operation selector mechanism of DK-76

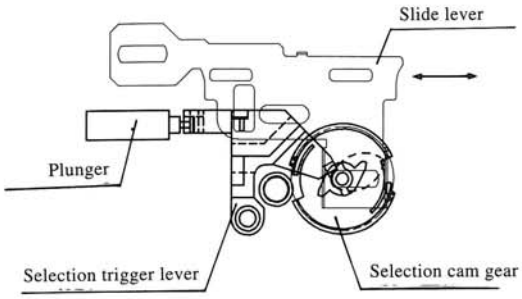

Figure 10. Structure of operation selector mechanism of conventional produc

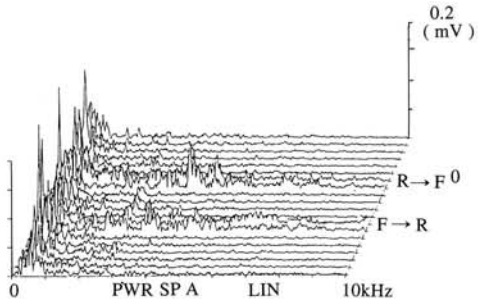

Figure 11. Spectrum of operation switching noise of DK-76

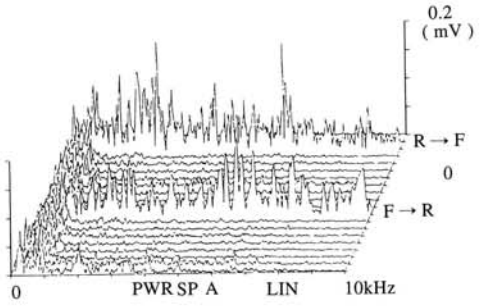

Figure 12. Spectrum of operation switching noise of conventional product

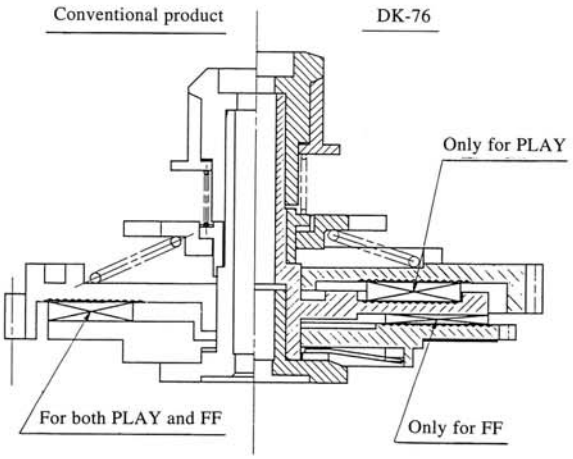

Figure 13. Slip mechanisms

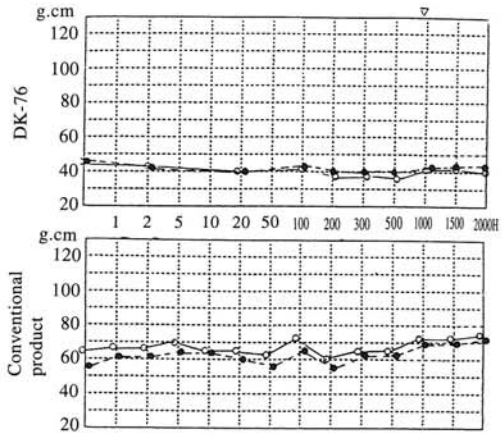

Figure 14. Play torque

5.2 Control circuit

5.2.1 Cassette deck control

The DK-76 has been designed as a cassette deck unit which contains a cassette deck controller (hereafter called the microprocessor) and drive circuits. Figure 15 is a system block diagram of the control circuit.

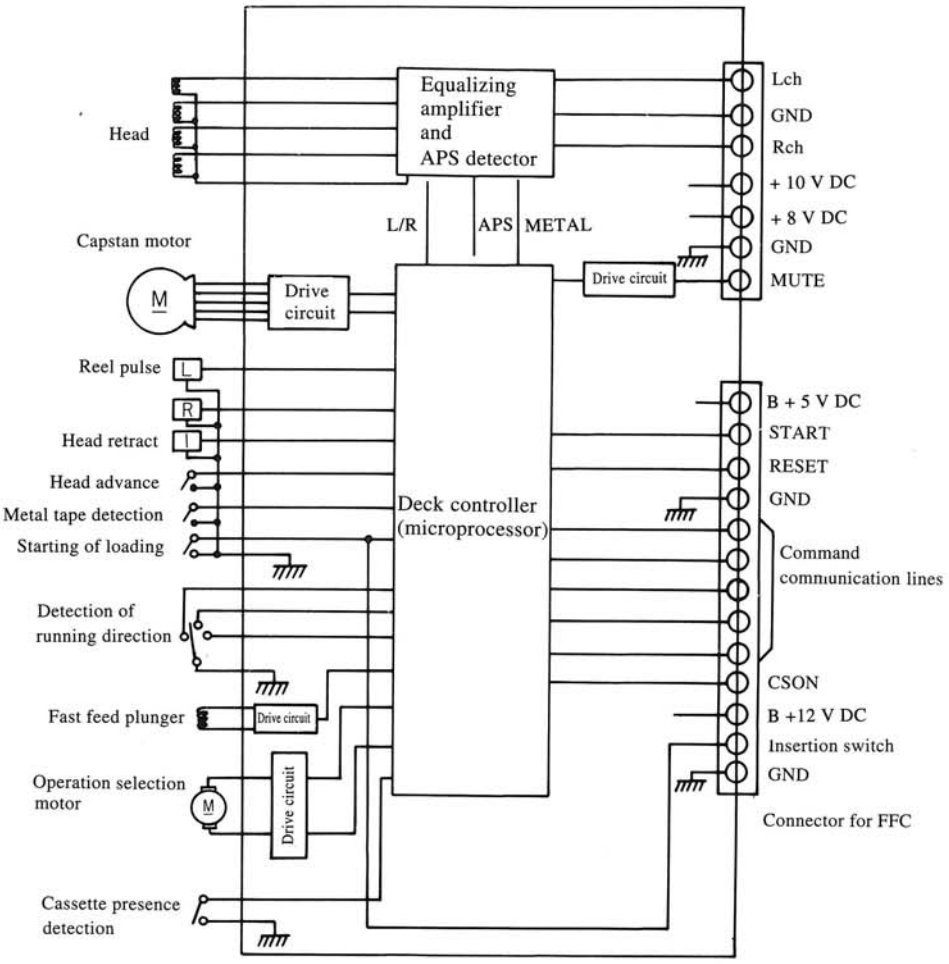

Figure 15. Control circuit block diagram

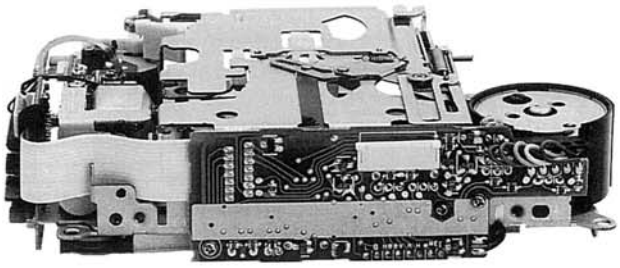

Figure 16. Back of the DK-76

The DK-76 initially had 32 wires for connection between printed circuit boards, including signal lines to switches and the motor. This number has been reduced to 20, including the equalizer output wires, by using a common ground wire for the switches and by introducing a microprocessor. The DK-76 is our first cassette deck having a connector for a flexible flat cable (FFC) with conductors arranged with 1-mm spacing. This has allowed the use of smaller printed circuit boards. It is also possible to check cassette deck operation and adjust the cassette deck when five communication lines (command lines) are connected to the power supply. Connection is also easy. Since a standardized control circuit is used, quality stability is assured. Figure 16 shows the back view of the DK-76 containing small printed circuit boards.

5.2.2 Microprocessor software

To achieve high reliability, the DK-76 has been designed not only with consideration on mechanical structure, but also with emphasis on the features of a microprocessor-controlled cassette deck. In fact, the DK-76 uses microprocessor software to achieve fail-safe functions and very accurate control. As a result, the DK-76 can prevent the tape from being wound improperly, take appropriate action in response to incorrect cassette insertion or abnormal cassette ejection, access the beginning of a musical piece accurately, and protect internal components when the tape or motor is locked. These cassette control features make the cassette deck operation easy. Table 3 gives a comparison between the DK-76 and other products in features for higher reliability achieved by using software control. As an example of the accurate control we achieved, the quickening of tape reversal detection is explained below.

If the take-up reel stops because the winding is too tight while the tape is running, the tape is drawn out by the capstan and pinch roller until the running direction is reversed. This detection time is shorter than that of our previous models, and the length of the tape drawn out is shorter. In this way, the DK-76 performs better. Figure 17 gives a comparison in tape reversal time between the DK-76 and conventional products.

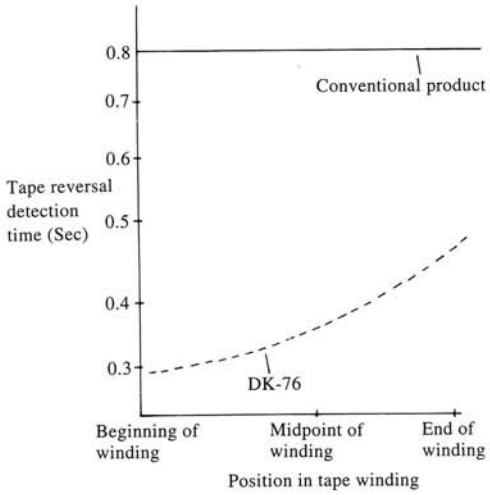

Figure 17. Tape reversal detection time

Table 3. Software-controlled features for higher reliability

Category	Description	Conventional product (Fujitsu TEN)	DK-76	Company A's product	Company B's product
Response to abnormal insertion/ ejection	The cassette is not loaded in a specified time.	○	○ (Ejection)	○ (Ejection)	○ (Ejection)
	The cassette is not ejected in a specified time.	○	○ (Loading)	○ (Loading)	○ (Loading)
	Standby state by trouble is established if repetitions of insertion and ejection fail to restore the cassette deck to the normal state.		○	○	○
Prevention of improper tape winding	Slack elimination during cassette loading	○	○		○
	Quick end-of-tape detection in PLAY mode		○ (0.4 s)	○ (0.5 s)	(1.5 s)
	The cassette is ejected in PLAY mode if the supply reel stops.		○ (10 s)	○ (13 s)	○ (2 s)
	Tape slack prevention at the time of transition from FF to PLAY and from REW to PLAY		○		(Mechanical brake only)
Accurate access to beginning of musical piece	Compensation for excess tape travel at REW access to the beginning of a musical piece		○	–	–
	Compensation for excess tape travel at FF access to the beginning of a musical piece		○	(None)	(REW)
	Sure music interval detection (independent of diameter of wound tape roll)		○	○	
Protection of tape and motor	End-of-tape detection in a constant time		○ (4 times)	○ (4 times)	○ (Twice)
	Detection of high-speed reel rotation during PLAY operation		○		○

6. Closing remarks

The DK 76 model for was installed in the Toyota Celica models after August, 1989 as the cassette deck for the Super Live Sound System option. This system is intended to produce top quality sound.

We have produced a cassette deck which has good performance, excellent sound quality, fashionable design and high reliability.

In the future, we must improve the quality and performance, lengthen the life, and reduce the cost. We are now marketing the DK-76.

Masato Takahata

Entered the company in 1980. He has been engaged in the mechanical design of cassette decks for car stereos, and has been in charge of deck mechanism planning since 1990. He currently works in the Audio and Video Deck Mechanism Division.

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